

## THE CLAIMS

What is claimed is:

1. A plasma-assisted dry etching method for etching a noble metal material, said method comprising:

contacting the noble metal material, in the presence of an oxidizing agent selected from the group consisting of oxygen and ozone, with an energized plasma composition comprising etch species from at least one halogenated compound selected from the group consisting of organic halogenated compounds, inorganic halogenated compounds and mixtures thereof, for sufficient time to at least partially etch said noble metal material, wherein the energized plasma composition contacting the noble metal material lacks nitrogen- and phosphorous-containing species.

2. The method according to claim 1, wherein the noble metal material comprises an Ir-based material.

3. The method according to claim 2, wherein the etch species comprise  $C_2H_6$  in the presence of  $O_2$ .

4. The method according to claim 1, wherein the energized plasma is energized by electromagnetic radiation.

5. The method according to claim 4, wherein the electromagnetic radiation has a frequency ranging from about  $1 \times 10^3$  to about  $1 \times 10^{12}$  Hertz.

6. The method according to claim 5, wherein the noble metal material comprises Ir.

7. The method according to claim 4, wherein the noble metal material comprises  $IrO_2$ .

8. The method according to claim 3, wherein the energized plasma further comprises a co-reactant to assist in the volatilization and removal of iridium products from the Ir-based material.
9. The method according to claim 8 wherein the co-reactant is selected from the group consisting of elemental silicon and quartz.
10. The method according to claim 3, wherein the etch species further comprises  $\text{XF}_2$ .
11. The method according to claim 1, wherein the oxidizing gas comprises an oxidant selected from the group consisting of  $\text{O}_2$ , and  $\text{O}_3$ .
12. The method according to claim 2, wherein the energized plasma is energized in a downstream microwave processing system.
13. The method according to claim 12, further comprising the removing at least one iridium product in the course of the etching process.
14. The method according to claim 1, wherein the halogenated organic compound comprises a compound selected from the group consisting of  $\text{C}_2\text{F}_6$ ,  $\text{C}_2\text{Cl}_3\text{F}_3$ ,  $\text{C}_4\text{F}_8$ ,  $\text{C}_5\text{F}_8$ ,  $\text{C}_3\text{F}_8$ ,  $\text{C}_2\text{Cl}_2\text{F}_4$ ,  $\text{C}_2\text{ClF}_3$ ,  $\text{CClF}_3$ ,  $\text{CCl}_3\text{F}$  and  $\text{CCl}_2\text{F}_2$ .
15. The method according to claim 14, wherein the halogenated organic compound comprises  $\text{C}_2\text{F}_6$  in combination with the halogenated inorganic compound  $\text{XeF}_2$ .
16. The method according to claim 15, wherein the energized plasma further comprises reactive species formed by reacting  $\text{C}_2\text{F}_6$  with elemental silicon.
17. The method according to claim 16, further comprising the removal of at least one iridium product during the etching process.

18. The method according to claim 17, wherein the at least one iridium product comprises an iridium-containing composition selected from the group consisting of  $\text{IrSi}_2\text{F}_4$ ,  $\text{IrSi}_3\text{F}_6$ , and  $\text{IrSi}_4\text{F}_6$ .
19. The method according to claim 16, wherein the oxidizing gas comprises  $\text{O}_2$ .
20. The method according to claim 2, wherein the Ir-based material is deposited on a high temperature dielectric material or ferroelectric material.
21. A method of fabricating a microelectronic device structure, comprising:  
depositing a noble metal material on a substrate;  
forming a pattern on the deposited noble metal material of a desired configuration;  
contacting the deposited noble metal material in the presence of an oxidizing gas selected from the group consisting of oxygen and ozone, with an energized plasma comprising etch species deriving from at least one halogenated compound selected from the group consisting of organic halogenated compounds, inorganic halogenated and mixtures thereof, to thereby etch the noble metal material, wherein the energized plasma composition contacting the noble metal material lacks nitrogen-and phosphorous-containing species; and  
continuing step (c) for a sufficient time and under sufficient conditions to form the microelectronic device structure or a precursor thereof.
22. The method according to claim 21; wherein the noble metal material comprises an Ir-based material.
23. The method according to claim 21, wherein the etch species comprise  $\text{C}_2\text{H}_6$  in the presence of  $\text{O}_2$ .
24. The method according to claim 23, the energized plasma is energized by electromagnetic radiation.

25. The method according to claim 22, wherein the electromagnetic radiation has a frequency ranging from about  $1 \times 10^3$  to about  $1 \times 10^{12}$  Hertz.
26. The method according to claim 25, wherein the energized plasma further comprises a co-reactant to assist in volatilization and removal of iridium products from the Ir-based wherein the co-reactant is selected from the group consisting of elemental silicon and quartz.
27. The method according to claim 21, wherein the oxidizing gas includes an oxidant selected from the group consisting of  $O_2$ , and  $O_3$ .
28. The method according to claim 23, wherein the energized plasma further comprises  $XeF_2$ .
29. The method according to claim 26, further comprising removing at least one iridium product during the etching process.
30. The method according to claim 21, wherein the halogenated organic compound comprises a compound selected from the group consisting of  $C_2F_6$ ,  $C_2Cl_3F_3$ ,  $C_4F_8$ ,  $C_5F_8$ ,  $C_3F_8$ ,  $C_2Cl_2F_4$ ,  $C_2ClF_3$ ,  $CClF_3$ ,  $CCl_3F$  and  $CCl_2F_2$ .
31. The method according to claim 22, wherein the halogenated organic compound comprises  $C_2F_6$ .
32. The method according to claim 31, wherein the energized plasma further comprises reactive species formed by reacting  $C_2F_6$  with a co-reacting species selected from the group consisting of elemental silicon and quartz.
33. The method according to claim 32, further comprising removal of at least one iridium product in the etching process.

34. The method according to claim 33, wherein the at least one iridium product comprises an iridium composition selected from the group consisting of  $\text{IrSiF}_3$ ,  $\text{IrSi}_2\text{F}_4$ ,  $\text{IrSi}_3\text{F}_6$ , and  $\text{IrSi}_4\text{F}_6$ .

35. A method for removing a noble metal residue from a microelectronic device structure, the method comprising:

contacting the microelectronic device, having deposited thereon a noble metal residue selected from the group consisting of platinum, palladium, iridium and rhodium, with a gas-phase reactive composition comprising a halide component selected from the group consisting of  $\text{SF}_6$ ,  $\text{SiF}_4$ ,  $\text{Si}_2\text{F}_6$ ,  $\text{SiF}_2$  radical and  $\text{SiF}_3$  radical, in an amount to remove noble metal residue from the microelectronic device structure, in the presence of an oxidizing gas selected from the group consisting of oxygen and ozone, wherein the gas-phase reactive composition lacks nitrogen-and phosphorous-containing species.

36. The method according to claim 35, wherein the halide is selected from the group consisting of  $\text{SF}_6$ ,  $\text{SiF}_4$ , and  $\text{Si}_2\text{F}_6$ .

37. The method according to claim 35, wherein the halide comprises  $\text{SF}_6$ .

38. The method according to claim 35, wherein the halide is selected from the group consisting of  $\text{SiF}_2$  and  $\text{SiF}_3$  radicals.

39. The method according to claim 35, wherein the halide is selected from the group consisting of  $\text{SiF}_2$  and  $\text{SiF}_3$  radicals and the halide is generated by reaction of  $\text{XeF}_2$  with silicon.

40. The method according to claim 35, wherein the halide is selected from the group consisting of  $\text{SiF}_2$  and  $\text{SiF}_3$  radicals and the halide is generated by passing  $\text{SiF}_4$  through an energetic dissociation source.

41. The method according to claim 40, wherein the energetic dissociation source is selected from the group consisting of plasma sources, ion sources, ultraviolet sources and laser sources.

42. A method for removing from a microelectronic device structure, a noble metal residue comprising iridium, the method comprising:

contacting the microelectronic device structure with a gas-phase reactive halide comprising  $\text{XeF}_2$  and an agent to assist in volatilizing and at least partially removing the noble metal residue from the microelectronic device structure.

43. The method according to claim 42, wherein the agent is selected from the group consisting of carbon monoxide, trifluorophosphine, and trialkylphosphines.

44. The method according to claim 43, wherein the agent further comprises an iridium halide species selected from the group consisting of  $\text{Ir(X)}_1$ ,  $\text{Ir(X)}_3$ ,  $\text{Ir(X)}_4$  and  $\text{Ir(X)}_6$ , wherein X represents the halide of the reactive halide composition.

45. The method according to claim 42, wherein, the gas-phase reactive halide composition further comprises a gas phase reactive halide species selected from the group consisting of  $\text{SiF}_4$ ,  $\text{Si}_2\text{F}_6$ ,  $\text{SiF}_2$  radical and  $\text{SiF}_3$  radical; and the microelectronic device structure is further contacted with an agent to assist in volatilizing and removing the noble metal residue on the microelectronic device structure.

46. The method according to claim 42, wherein the agent is selected from the group consisting of Lewis bases and electron back-bonding species.

47. The method according to claim 42, further comprising disposing the microelectronic device structure in a chamber and introducing a gas phase reactive halide composition selected from the group consisting of  $\text{SF}_6$ ,  $\text{SiF}_4$  and  $\text{Si}_2\text{F}_6$  that is continuously flowed through the chamber, in combination with an energetic dissociation source selected

from the group consisting of plasma sources, ion sources, ultraviolet sources and laser sources.

48. The method according to claim 42, further comprising disposing the microelectronic device structure in a chamber and introducing a gas phase reactive halide composition selected from the group consisting of  $\text{SiF}_2$  and  $\text{SiF}_3$  that is continuously flowed through the chamber, in combination with an energetic dissociation source selected from the group consisting of plasma sources, ion sources, ultraviolet sources and laser sources.

49. A method for removing from a microelectronic device structure a noble metal residue including at least one metal selected from the group consisting of platinum, palladium, iridium and rhodium, the method comprising:

contacting the microelectronic device structure with a gas-phase reactive composition comprising  $\text{SiF}_4$  in a sufficient amount to at least partially remove noble metal residue.

50. A method for removing from a microelectronic device structure a noble metal residue including at least one metal selected from the group consisting of platinum, palladium, iridium and rhodium, the method comprising:

contacting the microelectronic device structure with a gas-phase reactive halide composition comprising  $\text{Si}_2\text{F}_6$  in a sufficient amount to at least partially remove noble metal residue.

51. A method for removing from a microelectronic device structure a noble metal residue including at least one metal selected from the group consisting of platinum, palladium, iridium and rhodium, the method comprising contacting the microelectronic device structure with a gas-phase reactive halide composition comprising a halide component selected from the group consisting of  $\text{SF}_6$ ,  $\text{SiF}_4$ ,  $\text{Si}_2\text{F}_6$ ,  $\text{SiF}_2$  radical,  $\text{SiF}_3$  radical, and  $\text{XeF}_2$ , in an amount effective to at least partially remove the noble metal residue; the gas-phase composition (a) further comprising an oxidizing gas selected from

the group consisting of oxygen and ozone, and (b) lacking a nitrogen- and phosphorous-containing species.